REMARKS

Rejections under 35 U.S.C. §102(b) and 103

Claims 1 and 5-20 have been rejected under 35 U.S.C. §102(b) as being anticipated by Cao (U.S. Pat. No. 5,965,281). Claims 10 and 21 have been rejected under 35 U.S.C. §103 as being obvious over Cao (U.S. '281) combined with Yu et al. (U.S. Pat. No. 6,441,395). Applicants traverse this rejection and withdrawal thereof is respectfully requested.

In response to Applicants' arguments of March 17, 2003, the Examiner maintains the rejection for the reasons discussed in the "*Response to Arguments*". It appears that the Examiner finds Applicants' arguments insufficient to overcome the rejection, mainly based on the device disclose in Figure 15, of Cao.

The Examiner notes that the device of Figure 15 of Cao has two layers "16". Thus, the Examiner appears to be of the position that the first layer 16 along with layer 24 is equal to the conducting second layer of the invention and the second layer 16 (adjacent to layer 18) is equal to the third layer of the invention.

Applicants again traverse the rejection, particularly the interpretation by the Examiner of the device of Cao and withdrawal of the rejection is respectfully requested.

Teachings of Cao - US Pat. No. 5,965,281 -

Cao teaches a light-emitting diode wherein the active material is a semi-conducting polymer. A specific objective in Cao was to provide a light-emitting diode, which has high quantum efficiency and can be used with a high work-function cathode.

Cao discloses in column 10, lines 39-49, that the cathode, i.e. the electron injection terminal, used with the light-emitting diode has a high work-function that is equal to or greater than 4.0eV. As specific suitable examples of cathode materials Cao lists aluminum, copper etc., with aluminum being preferred.

Cao also discusses the anode of the device of the '281 patent in column 10, lines 16-37, wherein a number of suitable materials are mentioned that meet the requirement of being sufficiently thin to be semitransparent or transparent. Typical anode materials of Cao are metals, oxides, inorganic semiconductors and doped conducting polymers. However, many of the anode materials have a work function that is significantly lower than 4.5eV.

The device of Cao is depicted in Figs. 13-15, all of which are light-emitting diodes. In Fig. 13, the LED (10) includes a layer (16), which is an electroluminescent polymer mixed with an additive and which is sandwiched between the transparent anode (14) and a cathode (18). Figure 14, depicts a light-emitting diode which is

similar to the device of Fig. 13, except that an additional electron-injecting layer (22), which is made of a mixture of electrically active polymer and anionic surfactant additive, is provided between the anode layer (14) and the semiconducting or light-emitting polymer layer (16). Finally, Fig. 15 depicts a polymer-based electronic device in the form of a triode, with a polymer grid layer (24). The polymer grid layer (24) is a conductive polymer that is embedded in the active polymer layer (16), such that both of the layers (16) are disposed on either side of the conducting polymer grid (24). Cao clearly distinguishes between layer (16), which is an electronically active organic polymer mixed with an additive and the polymer material of the grid (24), which is defined as only being conducting.

Column 6, beginning at line 48 of Cao recites that the mixtures used in the devices include an electronically active polymer, which must be interpreted as being a semi-conducting polymer. Cao specifically mentions in column 6, lines 52-54 that the presence of the electronically active polymer may give rise to electronic effects, such as rectification, switching or electro-optical effects, such as electroluminescence. The additive is described in column 7, beginning at line 36, and is stated to be a highly polarizable organic material, typically an organo-sulfate or organo-phosphate. The effects of these additives, as an admixture

in the semiconducting polymer layer 16 or as a separate layer 22 (which is stated to be a mixture of the additive with a semiconducting polymer) is to enhance electron injection into the semiconducting material of layer (16). Cao further teaches that this, at the same time, allows the use of what the reference terms as a high work-function cathode.

As a result, Cao obtains a light-emitting diode, which shows a significantly increased luminance and improved quantum efficiency, for lower voltage levels and higher currents. As exemplified in Table 7 of the reference, Cao shows that the use of additives enables the improved performance with high work-function cathodes, i.e. cathodes that are made from contact material having a work function greater than or equal to that of aluminum, which is said to give the best performance.

The present invention and differences with Cao

Contrary to Cao, the present invention is not concerned with a photonic device, i.e. a light-emitting diode, but rather is drawn to an anode structure, which has an organic rectifier diode having an improved rectification ratio and wherein the diode junction is generated in a semiconducting polymer. Since the present invention does not concern light-emitting diodes, the present invention would not require transparent electrodes. Conventionally, it has been

regarded in the art to be advantageous to have an anode having a high work function and a cathode having an appreciably low work function in order to obtain efficient diode performance. To this end, light-emitting diodes use a transparent anode material such as ITO, which has a work function of about 5 eV and rely on aluminum cathodes, which have a work function of about 4.2 eV. Since ITO has a very high contact resistance, it is usually coated with a thin layer of a noble metal, such as gold or platinum.

The present invention addresses and overcomes the problems associated with providing a high rectifier diode by improving the charge injection efficiency of the anode and providing an anode with an appreciably higher work function than the cathode and the present invention achieves a much improved rectification ratio in such rectifier diodes. These aims are achieved with the present invention by providing a bilayer anode, wherein a conducting polymer is used as the hole-injection material to the semiconducting rectifier junction. A material, such as PEDOT-PSS, has the required high work function of about 5 eV, which is appreciably higher than that of e.g. the aluminum cathode. The present inventors have surprisingly discovered; however, that the conducting polymer is incompatible with conventional contact materials such as gold or platinum and ITO, because these materials have a tendency to form pin-holes in the conducting polymer deposited thereon. However, the inventors

further found that the conducting polymer in the anode could be used with any base material having a low contact resistance, such as copper or aluminum, and that this results in an anode having the same work function as the conducting polymer, even though the metallic contact material might have an appreciably lower work function, ranging from about 2 eV, in some instances, to 4.2 eV for aluminum.

The present invention has the associated advantages of allowing for the use of aluminum as a contact material in both the anode and cathode. In addition, the use of a conducting polymer in the anode serves to enhance the charge injection properties. Cao in Example 8 discloses that the transparent ITO anode is "replaced by semitransparent gold on a glass substrate" and also discloses the use of bilayer anodes, in which the ITO was over-coated by hole-injecting conducting polymers, specifically mentioned as polyaniline (PANI) and polythiophene (PEDOT-PSS). While these conducting polymers are the same as those used in the present invention, as discussed above, they cannot be used as thin films in conjunction with a material such as ITO or any other noble metal, due to the detrimental effect these materials have on the conducting polymer layer in the anode.

Cao has no appreciation for the fact that a conducting polymer used in conjunction with either a noble metal or ITO causes severe problems for the structural integrity of conductive polymer layer. Thus, there is no appreciation or suggestion in Cao of the present invention. Hence the present invention provides a rectifier diode having a high rectification ratio or an organic thin-film transistor having much improved charge injecting properties with the required anode properties, i.e. essentially bulk-limited hole injection and appreciably higher work function than that of the cathode, while being able to provide the contact material, both anode and cathode, as one and the same with an appropriate work function ratio. There is no disclosure or suggestion in Cao of these particular features of the present invention.

The present invention achieves a rectifying diode with a rectification ratio as high as 10^7. This value is at least four orders of magnitude than the dark-current rectification ratio that is found in light-emitting diodes, see e.g. Cao, col. 6, line 6. Claim 4 of Cao similarly recites that the light-emitting diode has a rectification ratio "of at least 10^3 or larger". While claim 4, recite how much "larger", it is known that dark-current

rectification ratios on the order of 10^4 have been achieved by other research groups. Thus, one skilled in the art would interpret "or larger" to mean on the order of roughly 10^4. It should also be noted that the present invention does not teach the semiconducting material with an additive for improving the electron-injecting properties of the light-emitting device and allowing what Cao terms a high work-function cathode. On the contrary, the present invention requires that the cathode shall have an appreciably lower work function than the anode, and this is surprisingly achieved when the same contact material is used, e.g. aluminum, in both the anode and the cathode, by coating the contact material of the anode with conducting polymer as the hole-injecting layer. The anode then obtains the work function of the conducting polymer, i.e. on the order of 5 eV or even higher. This is result is unexpected, and as a result the invention is able to provide a rectifier diode having an anode with high work function and with improved charge-, i.e. hole-injecting properties, as well as a rectification ratio which exceeds anything known in the prior art at least by 3 orders or magnitude. Any person skilled in the art will appreciate the advantage of being able to provide organic rectifier diodes with a high rectification ratio or anode structures with both a higher work

function and improved hole-injecting properties for organic semiconductor devices such as transistors. There is no suggestion in Cao of achieving these properties. As such, the present invention is not anticipated by or obvious over Cao and withdrawal of the rejection is respectfully requested.

With further regard to the rejection of claims 10 and 21, the Examiner suggests that the polymers (PANI or PEDOT) may have both an electrically conducting state and an insulating state. This Examiner's statement would apply to the semiconducting polymers, i.e. the electrically active polymer of Cao's layers 16 and 24 which are treated at length, e.g. in example 6 of Cao. However, the polymers of claim 10 are conducting conjugated polymers. Typically Cao also uses MEH-PPV suitably doped. The present invention also teaches the use of doped MEH-PPV. However with Cao, unlike the present invention, the doping is to display electroluminescence which is the ultimate goal for a light-emitting diode and the main concern of Cao. As such, the invention of claims 10 and 21 are further not obvious over Cao.

In summary, the present invention discloses essentially a rectifier diode with higher rectification ratio or at least a bilayer

anode with either a first layer of a base metal or an inorganic semiconductor combined with a conducting polymer, such that a bilayer anode with high work function and efficient hole-injecting properties is obtained. In a rectifier diode this combination allows for a rectification ratio that is at least three orders of magnitude higher than the dark current rectification ratio of light-emitting diodes as cited in Cao, or known in the prior art. The present invention and its associated properties are neither disclosed nor suggested by Cao. As such, the present invention is neither anticipated by nor obvious over the disclosure of the reference and withdrawal of the rejection is respectfully requested.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact MaryAnne Armstrong (Reg. No. 40,069) at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

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By [signature]
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